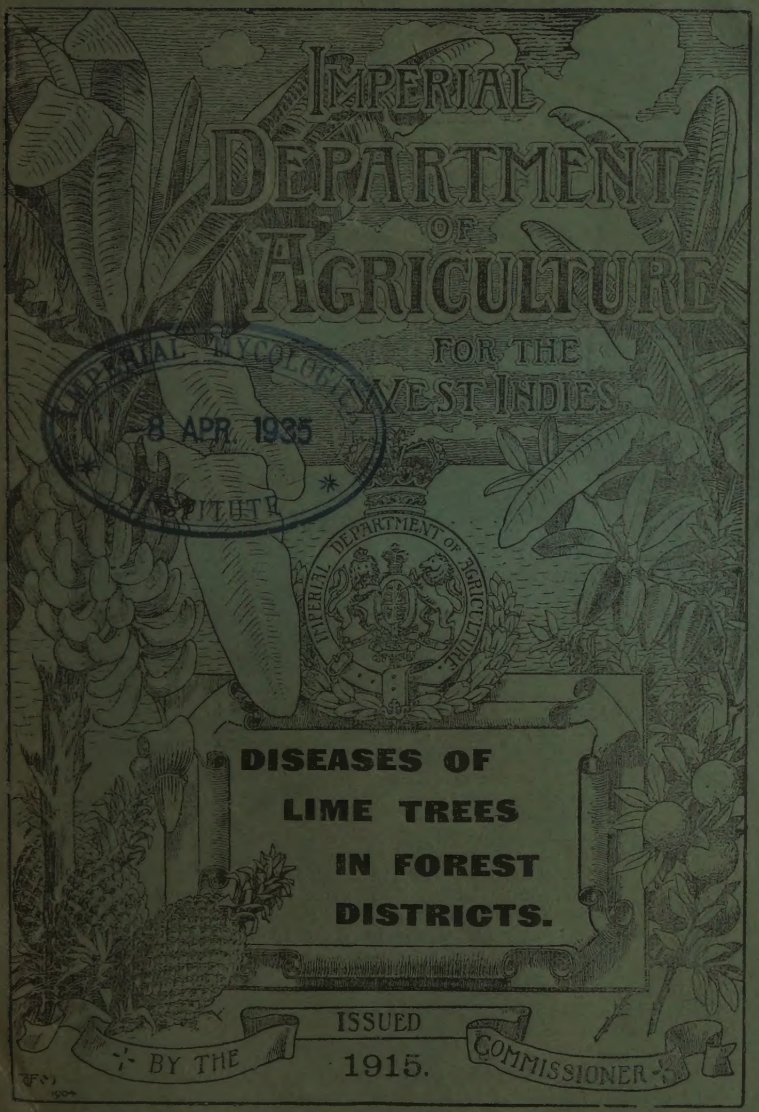

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IMPERIAL DEPARTMENT OF AGRICULTURE

FOR THE WEST INDIES.

DISEASES OF LIME TREES IN FOREST DISTRICTS,

BY

W. NOWELL, D.I.C.,
Mycologist on the Staff of the Imperial Department of Agriculture for the West Indies.

ISSUED BY THE COMMISSIONER OF AGRICULTURE.

1915.

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PREFACE.

The notes contained in this pamphlet embody the observations made by Mr. W. Nowell, the Mycologist to this Department, concerning certain root diseases of lime trees that are to be found principally in districts where limes are planted in areas recently cleared from forest growth.

As these diseases are due to fungus growths, and as it is essential that the nature and mode of life of fungi should be well understood in order that the remedial measures may be intelligently carried out, some space is devoted to a plain and simple description of what fungi are, how they live, how they are reproduced, and how they effect injuries on trees. Unfamiliarity on the part of planters with much that pertains to fungi and their habits, and the necessity for a clear understanding of these matters as affecting the means of control, are sufficient justification for the elementary introduction it is thought desirable to give at some length.

Mr. Nowell's notes will enable the observant planter to recognize the existence of these diseases when they occur, and they plainly indicate the measures that are to be adopted to control them. These measures are based on a careful study of the determining causes and are such as any careful planter can carry out. They embody the results of much original work

on the part of Mr. Nowell and his predecessors in office, and constitute a useful contribution to the knowledge of the subject.

The planter will recognize that the control of the diseases rests on his own exertions ; there are no short cuts to success, nor are there any specifics which can be used by way of cures.

Intelligent understanding of the causes, and diligent adoption of the methods of control based on this, are the points to be insisted on.

FRANCIS WATTS,
Commissioner of Agriculture
for the West Indies.

Barbados,
August 6, 1915.

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DISEASES OF LIME TREES IN FOREST DISTRICTS.

THE NATURE OF FUNGOUS DISEASE.

There are known to occur in Dominica three serious root diseases of lime trees, each caused by a fungus growing on the roots, destroying them, and so bringing about the death of the whole tree. Two of the diseases are so nearly alike in every respect that they are known under the one name of Black Root Disease ; the other has been named the Red Root Disease, and differs very much in appearance, though its way of working, the effects it produces, and the measures necessary for preventing its spread, are much the same as in the case of the first named diseases.

The willingness of the planter to adopt measures for the control of these diseases and his success in carrying them out depend on appreciation of the reasons underlying the methods recommended. For this reason it has been considered desirable to explain at some length the nature of fungi in general, and of this class of fungous diseases in particular.

The place of fungi in nature.

Fungi are vegetable growths, i.e., they are plants, but of a relatively simple kind, just as the mosses that grow in damp places or the green scums which grow in stagnant water are plants in the scientific sense of the word. There are in Dominica thousands of kinds of fungi, and it is necessary to realize that each kind is distinct and separate from the rest, and one kind can no more produce another than a guava tree can produce oranges. The forms which fungi take are many and diverse : the green mould which forms on a wet boot is a fungus, a mushroom is another. All are however alike in one respect : they can live only at the expense of material which has been formed by some plant or animal ; in other words, their food must have been to some extent prepared for them. There are fungi ready to take advantage of all classes of such material if the conditions are favourable ; they precede or share with or follow, as the case may be, the even simpler organisms known as bacteria, which live in a similar way. To mention only plant material : dead wood and bark, fallen leaves and fruits are all well known to be subject to decay, and such decay is in large part due to the action of fungi which live upon them and decompose their substance in the process of obtaining from them the food necessary for their own existence. Since fungi are usually rather delicate in structure and readily dry up, the external conditions most necessary for their development are damp, shade and still air.

So far only dead materials have been mentioned, and to these the great majority of fungi are absolutely confined. But amongst them there are some which are able to provide their own plant food by killing living tissues, and others which without killing any part of their host, live at its expense as do the ticks on a cow.

Conditions favouring root fungi.

To the class of those which kill their host the fungi of root diseases obviously belong. Fungi of this class which live on fruits or leaves or branches, or even stems, may or may not be serious in their effects on the plant; a disease which spreads to the collar as many root diseases do, touches the most vital spot. Working under the protection of the soil, in a climate like that of Dominica the fungus is not checked by lack of moisture, nor exposed to sun or wind. Moreover, existing as it does, not on the surface of the root but inside the bark and eventually deep in the wood, the application of external remedies, lotions so to speak, cannot be expected to be effective, while so far as internal remedies are concerned, we are confined to the very restricted range of substances, mostly of the nature of foods, which the roots will consent to take up.

It is clear that once a root fungus has got a footing, the conditions are heavily in its favour. The most profitable line of enquiry must be in the direction of learning how that footing is obtained, since only by virtue of such knowledge may we hope to be successful in measures of

prevention. With respect to the black root disease we may claim that sufficient definite information has been obtained to allow of the process being followed with a considerable degree of certainty. In the case of the red root disease our knowledge, as will be seen, is more fragmentary, but suffices for a definite decision as to the measures required.

Conditions in new clearings.

The trouble due to black root disease, so far as lime trees are concerned, is confined to forest estates established fairly recently, for the greater part on new clearings. It is instructive to consider the history of one of these.

When the woodmen have done their work of felling, and when as much material as possible has been destroyed by burning, the rest is left to the agencies of natural decay. Logs lie everywhere on the surface, and the soil itself is full of roots, large and small, which begin to starve for want of the food which only the green leaves can supply. Many of the stumps send up new shoots, but these even if left alone suffice to keep only a portion of the root system going, and leaving them alone is not the planter's policy. Eventually most of the roots die and the remainder tend to be weak and unhealthy.

All this provides great opportunities for fungi. In every forest region there are hundreds of species which specialise on just such work. In the natural conditions of the forest they maintain an existence on chance supplies: decrepit trees, dead branches, windfalls. They

may be seen in such situations anywhere one takes the trouble to look for them.

The means of reproduction of fungi.

A fungus growing on a dead tree is not like a fly bred out from a carcase, able to go bodily in search of new food. But just as a flowering plant produces seeds and depends on their distribution for the occupation of favourable situations by the new generation, so a fungus produces countless small bodies, fine as dust—its spores—each of which has the power, when carried by the wind or washed by water to the right place, of growing up in the form of its parent. The thing usually recognized as the fungus, i.e., the toadstool, the bracket standing out from a dead branch, the white or grey or black layer on the surface of the bark, is a structure for producing and liberating these spores; the actual working part of the fungus is to be found penetrating in every direction through the wood or bark, in the form of threads or strands or sheets of more or less cottony material, dissolving out and absorbing the substances it requires.

Individuality in fungi.

There is a considerable amount of specialisation amongst these agents of decay. A little difference of chemical composition or of physical structure in the wood or bark, of moisture or of shelter in the surroundings, gives one or another an advantage. Some are able to attack fresh material, others only to follow on and take what these have left. This possession of individuality is a point of great importance. The lack of

ability to attack living tissues makes the great majority of such fungi harmless to the planter, the possession of such an ability, confined so far as we know, in any but insignificant measure, to three species so far as lime trees in Dominica are concerned, makes these his serious enemies.

THE BLACK ROOT DISEASE.

The causative fungi.

The black root disease of limes is caused by one or the other of two species of a small group of fungi whose surname, so to speak, is Rosellinia. They resemble each other in general characters, and differ in smaller details. as orange trees and lime trees, for example, resemble and differ from each other. They may be discussed for the present as one.

Rosellinia does not take much part in the destruction of timber. One may search very many logs without finding a trace of it. For one thing it requires a very considerable and constant moisture. It can live and thrive on stems and branches if these are wet enough, but as a very general rule it finds congenial conditions only on material in close contact with or covered by the soil, hence mostly on roots, on branches partly or wholly buried, and, in damp and shaded situations, in the surface layer of mould rich in vegetable matter which is formed by the decay of leaves and twigs and the crumbling of rotting logs.

When a lime tree is killed by it, its progress up the stem is strictly limited by the prevailing conditions. If there is sufficient bush around the stem to keep the bark very moist it may go up for a foot or more. and the shelter of a big log near the tree can produce a similar effect ; usually its progress is stopped a few inches above the soil level. If the lime tree is cut down and the stem allowed to lie in the grass. it becomes diseased from end to end. while those branches which are raised up somewhat are attacked by other fungi, but not by Rosellinia. I have seen it growing on the underside of forest logs sheltered by over-hanging lime trees, and creeping over the dead leaves, twigs, and lime skins lying below the log, but the number of instances of its occurrence on logs actually seen in what now extends to several weeks of watchfulness for that kind of evidence, only amounts to two. .

The extent of its occurrence on the old roots in a clearing is naturally difficult to observe. The best index, though it is not necessarily a complete one, is afforded by the cases where the disease on a lime tree can be directly traced to such roots. A case has been seen where five lime trees growing round a very large stump have been attacked, another where a living stump had diseased roots, and a lime tree growing between two of its buttresses had become infected. From first to last a good many cases have now been investigated in which the roots of diseased trees have been found to be in contact with roots of

forest stumps bearing the same fungus. Many more cases, assumed to be of a similar nature, have had to be passed over for want of time or means to uncover the roots. But the fact remains that, considering the area covered, the number of such cases does not appear to be large. Most of the lime trees lost are infected one from another. It is the basis of hope in dealing with the disease that Rosellinia is under natural conditions a somewhat rare fungus, and that the original centres of infection, in the shape of forest stumps bearing the fungus, appear to be relatively few. There is strong reason to believe that the number of species of forest trees liable to the attacks of the fungus is quite limited, and that the presence of the stumps of these especially susceptible trees in clearings has a good deal to do with the distribution of the disease. It is well known that there is such a special susceptibility in the case of certain cultivated and semi-cultivated trees: besides limes and cacao, it is found that avocado pear, breadfruit, pois-doux (*Inga* spp.), hibiscus, and acalypha are very liable to attack from one or the other species of Rosellinia.

I have found it difficult to get sufficiently accurate information as to the identity of the forest trees most concerned. A large number of cases certainly occur in connexion with stumps of the chataignier (*Sloanea* spp.) type, but what species of chataignier, or if indeed in many cases it really is chataignier, or as has been suggested, bois riviere (*Chimarrhis cymosa*) I am unable to

say. This is a subject on which accurate observations by planters would be very valuable. Information is solicited, but with the caution that inaccurate determinations are much worse than useless. In the notes on black root disease in the Dominica Agricultural Report for 1912-13, Mr. F. W. South, late Mycologist of this Department, lists mahoe cochon (*Sterculia caribaea*) as a susceptible tree.

It may be objected that the evidence as to the connexion between diseased stumps and diseased lime trees would work just as well the other way; that the lime tree may have been attacked first and have infected the stump. Wider considerations, however, weigh strongly against this view. In the first place, the disease is unknown on the coast estates, which have no recent clearings. That immunity might be regarded as possibly due to the much lower rainfall. But, so far as careful enquiry has enabled me to ascertain, on those few forest estates with high rainfall where the clearings are old enough for the stumps to have disappeared, and where limes have now replaced the cacao which in most cases was first planted, there is little or no trouble from the disease.

Rosellinia in cacao plantations.

In the second place, we have the experience of cacao planters not only in Dominica, but in St. Lucia, Grenada, and according to published information, in the French islands and in Jamaica. There is an old and familiar tradition in these places that when one of the avocado or

breadfruit trees growing in the cultivation dies, the cacao trees around it invariably die too. The idea was, and still is among the uninformed, that the dying roots emit some poison, but we know now that it is not a disembodied virus, but a living organism in the shape of a Rosellinia, one of the same species which attack limes, which is responsible for the mischief. The avocado is particularly susceptible to that fungus. Under some circumstances, perhaps only when in a sickly condition, it contracts the disease, presumably from chance spores brought from a distance. However that may be, once established on the pear tree, the spread to the roots of the cacao is very evident, and beyond the possibility of doubt.

Direct evidence of infection on lime trees.

Lastly, there is the direct evidence of one of the cases mentioned above, of a log which bore the fungus. The log was on the surface, the roots of the adjacent lime tree had not yet become visibly infected, but a branch was resting on the log, and that part of the branch which made the contact had become infested with the disease. This, and a similar case where a living branch touched infected surface mould, are the only cases of infection of living branches I have ever seen or heard of, and there is little room for doubt that what took place there by a somewhat rare combination of circumstances, where it was visible, takes place regularly in the soil where the conditions for its occurrence exist commonly, but where the process cannot be so clearly followed. It may be mentioned that a native shrub growing on the log was also diseased.

Specific nature of the infection.

The conditions set out above as to the nature and limitations of Rosellinia may serve to some extent to answer the question which has not unnaturally been raised—why, if the disease is communicated from logs and stumps, any lime trees escape at all. It has been shown that not any fungus, not fungous decay in a general sense without reference to the identity of the fungus involved, can cause the disease. It depends on infection with a special organism as definite as the malaria parasite or the typhoid germ. A man may swallow a hundred species of bacteria, none of which finds the conditions prevailing in the human body to its liking, and nothing happens. Include the typhoid bacillus, which by chance or adaptation is able to live and multiply in the alimentary canal, and if the man's natural resistance is low, the disease will ensue.

Natural resistance to disease.

The question of natural resistance is an important one in respect of plant diseases as well. Many of them are serious only when their host is weakened by circumstances unsuitable to its growth, and have negligible effects on vigorous plants. In the case of Rosellinia disease of lime trees the reverse seems rather to be the case. Very commonly the best trees are attacked, and conversely there are large areas of poor trees amongst which the disease is rare or absent. No explanation which will cover all the circumstances observed in connexion with this fact has yet been framed.

The possibility of finding a resistant stock upon which lime trees can be budded affords hope of a simple means of control. So far, careful enquiry seems to show that the sour orange possesses such a resistance, and as large a number as possible of budded limes are now being distributed for experimental planting in diseased areas. It is too soon yet to include this among the recognized remedial measures.

Contact infection.

We may now follow up the story from the point at which there exist in the clearing one or more centres of disease in the shape of diseased stumps, it being understood that it is the attached roots, rather than the actual stump, which carry the fungus. As the root system of a lime tree planted in the neighbourhood of such a stump extends it comes in contact at one or more points with the fungus-infested roots, or it penetrates into the infested vegetable mould which may exist in their neighbourhood. Working from such a base, the fungus is able to attack the living bark of the lime root, starting a dead patch upon which it establishes itself, and then slowly extending, killing the bark before it as it goes. It crosses from one root to another by the same process, examples of which may be seen by anyone who cares to expose the roots of an infected tree at a fairly early stage.

Distinctions between the two species.

It is easy to distinguish upon the roots which of the two Rosellinias is at work. On peeling the bark from the wood, evidence of the one, *Rosellinia Pepo*, is seen in the shape of

PLATE 1.

Rosellinia Pepo: White mycelium under bark. Nat. size.

PLATE 2.

Rosellinia bunodes: Mycelial strands in bark of lime. $\times 1\frac{1}{2}$.

flattened fans and streaks of white spreading out over the surface of the wood and in the bark (Plate I); while the other, *Rosellinia bunodes*, forms very numerous blackish thread-like lines and dots in the same situation (Plate II). The threads of the latter species finally penetrate in all directions through the wood of even thick roots; they may be seen on very close examination to have a white centre. *Rosellinia Pepo* does not show in a recognizable form beneath the surface of the wood.

The disease on the collar.

Working its way along the roots, and through the surface mould if such is present and is damp enough, the fungus sooner or later reaches the base of the stem, where it finds congenial conditions in the hollows between the main roots. When the crown of roots is free from earth and moss, and at the same time there is no close shelter such as may be due to weeds or low branches, the progress of the disease round the collar may be checked at this stage by the exposed bark being too dry for it to attack. But though checked it is not stopped, since it can work round the underside of the adjacent root into the next hollow, and so on. Even if the roots could be cleared until the tree was more or less on stilts and the fungus thus stopped from crossing at the crown, the interlacing of the outer roots would enable it eventually to get round to them all. Nevertheless, the clearing and ventilation of crown and collar is a desirable hygienic measure. Certain cases have recently been seen, and they may be commoner than had been

suspected where Rosellinia had gained its first foothold on sodden bark in a hollow between the main roots; these were strongly suggestive of infection by spores, possibly direct in some cases but in others clearly by way of a preliminary infection of the surface mould, communicated to small roots directly attached to the trunk. Such consequences are prevented by a clean and dry condition of the bark and by the free admission of air and sun to the surface of the soil. In an experiment on a forest estate, the application of lime-sulphur wash to the crowns and collars of the trees has kept them beautifully clean for about six months wherever the circulation of air was at all good. The adoption of this precaution on a general scale is perhaps too much to expect, but it should be applied to all areas regarded as being in special danger of infection. It is effective, moreover, in cases of collar rots, of which a close inspection will often reveal a surprising number following upon cutlass or hoe wounds made in weeding. This does not by any means apply to forest estates only.

Attempts at recovery.

When Rosellinia passes from the roots to the collar of the tree it is the beginning of the end, though it is surprising what a long fight the tree will often make. As the bark near the soil level is killed, tufts of new roots are pushed out from the sound bark above, and sometimes get a good hold of the soil. In this way trees are enabled to struggle on a little longer, but I have never seen a convincing case of recovery by this

means, and it is certain that a policy of waiting for such a chance is not worth consideration.

Until the encircling of the stem is quite complete, and even for some time afterwards, the general appearance of the tree is often quite unaffected. The earliest outward sign of the disease in such cases, so far as I have seen, is the production of an abnormally large crop of fruit. Presumably the production of flowers would be equally striking, but this I cannot say from observation. Before this crop of fruit has had time to ripen the foliage drops, often with such suddenness that the ground is carpeted with leaves still green. The appearance which the tree then presents is a familiar one in the affected districts : its branches mostly bare of leaves and hung with shrivelling and prematurely yellow limes. In an observed instance a tree of perfectly healthy appearance, with abundant dark foliage, was found on October 20 to have its bark all round and for some distance up the stem infested through and through with Rosellinia. It remained green until November 17, and then the change from healthy foliage to naked twigs was completed in from twenty-four to thirty-six hours. When relieved from loss of water by the fall of the leaves a tree may put out a few small shoots and linger for some time before it completely dies. In other cases where the infestation becomes more general upon the roots before the stem is girdled, defoliation is more gradual and may

The final stages.

be preceded by yellowing of the foliage, but the end is the same.

The production of cosnidiopores.

It is necessary to go back a little in this description to take up the important question of the means of reproduction of the fungus. So long as it is working underground the fungus is subject to disadvantage in this respect. It would be of little use for it to form spores, since means for their distribution would be lacking. Consequently it takes advantage of any opportunities which occur of reaching the open air for that purpose. Such an opportunity sometimes presents itself when in working along a root it comes to an exposed knuckle, and always when it reaches the base of the stem. In such a situation, without taking the time necessary for its rather slow progress in and beneath the bark, it sends up an external growth on the outside of the bark which covers it with a greenish-black or smoky felted mass of somewhat silky material, which lies close to the bark and looks rather like the wet fur of a drowned rat. This growth is much better developed in the case of *Rosellinia Pepo*, and in that species has when fresh a conspicuous whitish border on its advancing margin. In both species production of the spores on the black layer soon follows, and there is no visible difference between the two species in the form and manner of their production. The exposed surface becomes covered with rather stiff upright black bristles, of the fineness of a human hair and about $\frac{1}{16}$ inch in length.

PLATE 3.

Rosellinia bunodes: Conidial fructifications. × 4½.

PLATE 4.

Rosellinia bunodes: Perithecia. ×4.

Each spreads at the top into a sort of brush, and on this are produced the minute spores, which cover it in a whitish powdery mass and are given off like smoke when it is disturbed. Dead vegetable material of all kinds, but especially roots and stems, invested by the fungus may be found crowded with these fructifications. (Plate III.)

The production of ascospores.

In the case of *Rosellinia bunodes* they are soon followed by another type of reproductive growth of a more permanent character. This takes the form of black roundish bodies approaching $\frac{1}{10}$-inch in diameter, covered with coarse, somewhat scale-like projections, and of a hard charcoal-like consistency. (Plate IV.) They are hollow, and within them black spores are slowly ripened which are larger and have a much more resistant covering than those before mentioned. It is probable that like the similar spores of other fungi which are better known, they are capable of withstanding considerable exposure and of keeping alive for a long time if they do not previously reach a situation suitable for their growth. It is not known how these spores, when they become ripe, are distributed. They do not appear to be very suitable for carriage by wind. Rosellinia disease in cacao cultivation has been noticed rather frequently to follow the direction of water courses, and this may have been brought about by water carriage of the spores.

The corresponding reproductive bodies in *Rosellinia Pepo* are formed much less readily, being met with as a rule only on the stumps of trees long dead. They are larger than those of *Rosellinia bunodes*, having a diameter of about $\frac{1}{8}$-inch. Their surface, in contrast with the character in that species, appears smooth to the naked eye, though seen to be slightly roughened in fresh examples when viewed through a lens. Not only are the reproductive bodies in this species slow to appear, but the spores seem to come very rarely to maturity, and in spite of long and careful search it is only recently that ripe spores have been found.

It seems probable, though it has not yet been established, that in the case of both species the type of spore first described, which is produced in very great abundance at a comparatively early stage, plays the principal part in the distribution of these diseases from place to place The matter is one for further investigation.

TREATMENT.

Basing our ideas upon the foregoing account of the origin and distribution of black root disease, the scope and possibilities of the measures to be taken for its control are clear enough.

We may put aside attempts to cure infected trees as in most cases hopeless and in the remainder doubtful, and as involving so much skilful surgery as to make them impracticable on

any but the smallest scale. The available energy is best directed towards measures which guard against infection.

The methods of infection may be set out as follows:— Methods of infection.

A. Contact Infection.

1. from the roots of the forest stumps.
2. from the roots of affected lime trees

B. Spore Infection.

3. from original sources, i.e., from the forest.
4. from secondary sources, i.e, from lime trees and other infected material in the clearing.

I do not consider that vegetable mould in which the fungus is present acts to any notable extent as a reservoir of the disease. Its importance lies in its service as an intermediary in either of the above methods of infection.

The disease when it first appears on the lime trees in a clearing is believed to come in the great majority of cases from bases of infection formed by infested forest stumps. It is impossible, under existing conditions, to remove these stumps before planting. It is also impossible to prevent the chance occurrence upon them, or certain of them, of Rosellinia, which is in all probability a native fungus, generally though perhaps scantily distributed through the forest.

A close watch should therefore be kept upon the trees from the beginning. Where a Inspection of trees.

case has occurred the surrounding trees should have their collars and crown roots cleared of soil and periodically inspected; by this means infections can be detected long before the leaves begin to fail. The use of lime-sulphur to keep the bark of the collar clean is a great advantage under these circumstances.

When an infected tree is found it is well that action should be prompt. If it is so far advanced that the fungus is producing spores, then before it is disturbed the spore-bearing surfaces should be flamed with a torch or by burning trash of some description around them. This disposes for the time being of the means of aerial dispersal of the fungus, and removes what is otherwise a real danger of the carriage of infection on the persons and implements of the labourers.

Isolation of contacts.

The next step is to prevent, by trenching, spread through the surface mould and by contact underground. In a regular field, with ordinary distances of planting, the roots of the lime trees form a continuous system of contacts, interrupted only by the deep drains. By the time a tree is so far diseased as to be noticeable, the probabilities are great that the roots of one or more of the neighbouring trees have also become infected. It is required to break the connexion between the infested roots and those of the surrounding healthy trees; and to be reasonably sure of doing this, it is necessary to carry an isolation trench outside the trees in

contact with the one diseased. Thus, in an undrained field, if D in the first diagram (Fig. 1) represents a diseased tree, C the possible contacts, and H the healthy trees, the isolation trench should take the course indicated by the unbroken line, and will include nine trees.

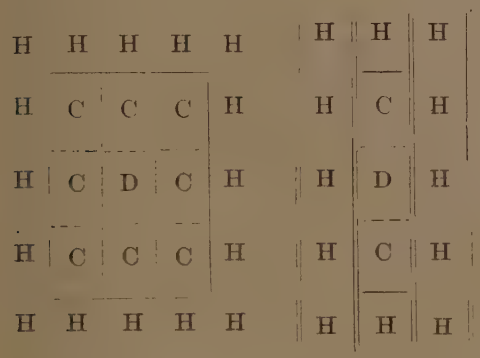

Fig. 1 Fig. 2

Neither the roots of the trees nor the course of the disease follow regular lines, and it is quite improbable that all the eight contacts are infected, but there is no practicable means of knowing which remain free. In order to save those which are still uninfected, it is advisable to cut up the enclosed area chess-board fashion as indicated by the dotted lines. If these secondary trenches are omitted it is likely that the contacts will all go off sooner or later. In many cases trees in such a position show the signs of attack

only after a considerable period of slow development of the disease underground. The original tree has been removed and forgotten, and so the later losses do not strike the planter as having any connexion with the first.

Single-row trenching.

Compare now the case represented in the second diagram (Fig. 2) where a permanent drain (denoted by a double line) exists between every row and the next. All that is required for isolation is the cutting of cross trenches between C and H to separate contacts from healthy trees, and secondary cross trenches between D and C to save the contacts if they do not prove to have become infected. The length of isolation trench required is reduced to one-sixth. It will be objected that the provision of the drains in the first instance will involve much more expense, but apart from such purely agricultural benefits as may be obtained, the difference is a very practical one between cutting trenches in a systematic way, and at a convenient time, on the one hand, and on the other hand, having to do it as an emergency measure, it may be at a time when it is highly inconvenient. I would suggest that the expense of draining should be discounted by regarding it as a system of insurance, whereby from each sporadic case of disease which occurs two trees only, instead of eight, are exposed to root infection. Such a system would prevent the development of the large open spaces, extending sometimes over the sites of dozens of trees, which are

the most disquieting feature of clearings where this disease has become well established. Into the arguments for this type of draining as an agricultural measure I do not propose to enter, but to be content to point out that there are instances in Dominica of its adoption on such grounds alone. The most serious objection I have heard urged against close draining concerns the inconvenience and loss experienced in the collection of the crop, but I doubt if this comes near to balancing the advantages of the system. On steep slopes, of course, the trenching will have to be carried out with due regard to contours and the danger of slips and of wash ; on all recent clearings there will be breaks due to large stumps There are some situations where the method is quite out of the question, but they afford no argument against applying it where difficulties are nonexistent or can be overcome. It is not necessary, from the point of view of root disease, that the drains should conduct water ; indeed, where loss of surface soil by wash is feared more than the alternate danger of water-logging, it may be advisable deliberately to check their function in this respect. They may then be periodically cleaned out and the deposit returned to the soil. It gives a clearer point of view if the system is regarded as one of permanent isolation trenches with a secondary function as drains rather than as one of drains in the first instance.

I have been informed by a planter who

adopted this method on his own initiative that it has proved so successful as to entirely alter the prospects of his estate, and an agricultural officer who has seen the results is enthusiastic in his appreciation.

Isolation of diseased areas.

Leaving the question of single-row trenching to return to things as they are, there are two commonly existing situations which need to be dealt with. These are (1) the case where a large patch of trees has already been eaten out of a field, and the disease is spreading outward around its circumference, and (2) the case where one or more trees have been attacked around a large forest stump, infested or likely to become so, which together with its heavy roots prevents the cutting of trenches over an area which may include quite a number of trees. In both cases the procedure has to be modified to suit each individual set of circumstances, but still follows the simple principles set out above. Where roughly parallel main drains or watercourses exist on each side of the area, they should be joined across above and below to establish an outward limit, even though it may be a wide one, to the spread of the infection. Then working inward from this, successive trees or rows of trees which appear healthy may be separated off wherever it is possible to dig a trench, and the disease thus confined to the narrowest limits.

It will have been seen that I am not an advocate of circular trenching around diseased

trees. The extent of the existing infection can never be ascertained by inspection, and a wide circle, while enclosing many healthy trees, may prove too narrow to include some line of infection that has run off in advance of the general spread. A circle leads nowhere, whereas a system of squares may be added to at any point and be carried in any direction, and is capable of easy subdivision. It has moreover the great advantage of linking up with an existing or prospective drainage system.

Methods of trenching.

As regards the form of the trench itself, there is but one essential so far as root disease is concerned : that it should be deep enough to cut through all the roots passing across its situation. When digging near an infected tree, the earth removed should be thrown inward as a precaution against the scattering of possibly diseased material among the healthy trees. This refers more particularly to secondary trenches ; the outer trench should be put far enough out to avoid, in general, the chance of finding such material. The earth should be distributed, not banked at the edge of the trench, unless put there in exceptional circumstances with the express purpose of avoiding wash. Under no circumstances however should the collar of the tree be earthed up. Roots passing into the healthy area should be followed up and removed so far as this can be done without much injury to other roots. It would be well if cut ends of roots were painted.

Prevention of spore infection.

Having provided against infection by contact, there is still infection by spores to be dealt with. Experience has shown that it is more difficult for planters and their assistants to realize the importance of the steps to be taken against this more insidious form of danger. To take an analagous case: it has been accepted for centuries that certain human diseases could be contracted by close proximity to an affected person. It has only in recent times been realized that the germs of such diseases may be widely spread to a distance by various intermediate agencies. In those cases, and in this of root disease, the information has to be taken on trust from those who have made a special investigation of the subject; but an attempt has been made in the first part of this paper to give an indication of the evidence on which the advice given is based.

The production of spores, it has been explained, takes place on any exposed area or piece of infested material. It commences usually on the collar of the tree, since that is the place where as a rule the fungus first reaches the open; it continues for a long period on that and any other portion of the tree which by reason of dampness is accessible to the fungus. The only practical way to prevent spore production is to destroy by fire the material infested and any that is likely to become so.

Destruction of diseased material.

The diseased tree should be cut down, the stump dug out, and the roots followed up and

removed as completely as possible. It is convenient for the labourers to have baskets handy into which the small roots can be thrown as they are dug out.

The whole tree should be cut up and stacked for burning. In a wet period this is the biggest difficulty in connexion with the treatment of the disease ; a kerosene blow lamp would be a very useful appliance to have for scorching and for starting fires. The first favourable opportunity should be taken of getting the fire going, and if not at first successful the efforts should be repeated until they are. Mere scorching is very useful as a preliminary measure ; as pointed out above, it makes handling safe ; but wood so treated soon begins to produce spores again if left lying about.

In some clearings it may be necessary to choose a convenient situation and carry to it everything to be burned, but such transportation has obvious dangers and ought to be preceded by the scorching of such material as is already diseased.

The use of lime.

Lime worked into the soil after a tree has been removed hastens the decay of any roots and twigs left behind, and by virtue of its alkalinity is believed to make the soil conditions less suitable to the survival of the fungus. When the lime can be used unslaked it has a more direct fungicidal action, but in forest districts the difficulties of transportation and the dampness of the climate usually make this impracticable.

The use of sulphur.

Powdered sulphur similarly applied has been used to some extent in St. Lucia, but what amount it contributed to the success of the measures adopted is not known. It has fungicidal properties, and where it can be got cheaply from local sources is worth using, but only as an additional precaution.

Sulphur and lime are alike to be regarded as auxiliary agents. First reliance should be placed on drying out the soil as thoroughly as possible by exposure to sun and wind. It follows that the surface of the vacant spots should be kept clear of bush.

Survival of supply plants.

On the thoroughness with which the cleaning-up is done depends the chance of survival of an early supply plant. It has been found in St. Lucia, where we have longer experience of this disease on cacao, that where the work has been carried out under the personal supervision of the planter, supplies put in a month afterwards have remained healthy. The longer the delay the greater the chance of survival. It must be remembered that a supply may do well for a few months while its roots occupy the site from which the stump was removed, and then become infected from some outlying fragment of the old tree as its roots spread wider. Such cases have been definitely traced.

The question of necessity for treatment.

There is nothing new in principle in the measures prescribed above; for the greater part they are such as have been recommended for many

years in various parts of the world, and repeated in all the articles concerning this and similar diseases in the publications of the Imperial Department of Agriculture. In St. Lucia, so far as the nature of the ground has permitted the use of these measures against the attacks of *Rosellinia Pepo* on cacao, the experience of the planters who have adopted them has been that if carried out under the supervision of a responsible person, they have been entirely successful. Imperfectly carried out they fail of their effect. The question of their adoption is purely an economic one.—Is the amount of loss, present and prospective, sufficient to justify the expenditure of time and money necessary to prevent it? This must be answered by the planter himself, and if he answers in the negative he bears the responsibility of the decision. Should the prescribed measures be taken and found ineffective, then he may justly call on his scientific advisers for an explanation and ask that the subject be re-examined. One thing must be very carefully kept in mind in making a decision: that the disease is a cumulative one; each tree that contracts it infects as a rule not merely one, but several more. The considerations arising from the fact that a dead tree takes at least five or six years to replace need no emphasis.

THE RED ROOT DISEASE.

The red root disease of lime trees is one of which we have much less experience than of the

black. It is known as yet only in Dominica, and until recently had been definitely recognized only on one or two estates. It is now known on several more. To find a close comparison for it we have to go to the descriptions of a similar disease of Hevea in the rubber plantations of Ceylon and Malaya. The fungus which causes it is less definite in its characters and more liable to confusion with other fungi than is the case with the Rosellinias, and the methods of spore production are as yet imperfectly known.

Distribution.

A distinctive feature about its distribution is that it is not confined to the newer forest estates. It occurs in two or three known instances on old established cultivations. Its relationships however are such as to lead us to suspect that, like the Rosellinias, it has its original home on decaying roots or logs; there is good evidence in the case of the closely comparable Ceylon fungus that this is so, but as regards the Dominica species there is as yet no proof. What is regarded as proved, and what is most essential to the planter is that the fungus is definitely parasitic on the lime tree, that it is communicated upon the roots from one tree to those around it, and that it is as capable as the black root diseases of opening up large gaps in a lime field, if measures are not taken to stop it.

The nature of the attack.

The effects of the disease are usually visible for a longer time in the foliage of the trees than is the case with Rosellinia attack, so that it has the appearance of being slower in its action.

This comes from the fact that the root system may be gradually destroyed without the girdling of the collar which is characteristic of Rosellinia and brings the victims of that fungus to a sudden end. The red root disease varies in different cases. Sometimes a soft rotted patch is seen extending on the collar at a fairly early stage while much of the root system is still sound, but very often in the cases I have examined the foliage had become thin and yellow, and the tree in some cases was nearly dead before any damage was visible in that region.

Symptoms.

When the roots of a sickly looking tree are laid bare, the disease is seen advancing along them in the form of a soft rot of the bark accompanied by a disagreeable smell. For some 6 inches to a foot of the region nearest to the healthy portion of a root the surface of the bark shows a greenish black discoloration, behind which the bark is rotted, and easily comes away. Apart from this appearance, the only definite symptom upon which one can depend for the identification of the disease on the roots is the presence between the layers of the bark, and between the bark and the wood, of certain flat branching strands. (Plate V.) These may be $\frac{1}{4}$-inch broad in their older parts. In well developed examples they divide several times, the main branches keeping their ribbon-like form and being mostly blunt and rounded at the tips. They may however develop a secondary system of finer semi-flattened branchlets along their margin, producing a sort

of fishbone pattern. There may also be produced on the margin of the strands, short pink threads to which allusion will be made later. The advancing tips of the strands are whitish and papery; further back the strands are brownish-red and rather fleshy; still further back the colour becomes dark brown. When old they lose their consistency, and are with difficulty recognizable as blackish streaks on the wood or in the bark.

A light brown discoloration extending deeply into the wood accompanies the advancing strands, and has been seen beginning just in front of their white tips as they penetrated into what was to all appearance perfectly healthy tissue.

The pink threads, less than $\frac{1}{4}$-inch in length, already mentioned as occurring at some points along the edge of the flat strands, may be seen projecting from the diseased bark at the collar and in the angles of the roots, often below ground. Small white clusters of spores are borne at their tips when they are fresh. These spore-bearing structures are never abundant, and are usually very scantily produced. It is not known what part they actually take in the spreading of infection.

Treatment.

There is no question as to the spread of the fungus by contact underground; that has been definitely proved. Hence it is necessary to treat the disease in exactly the same way as the black root diseases. Further information is

PLATE 5.

Red Root Disease : Mycelial strands beneath bark of lime root.

desirable as to the effect of draining, manuring, or liming upon diseased trees, and an experiment is in progress with this in view.

PINK DISEASE.

Distribution and symptoms.

In sheltered clearings on estates with a high rainfall a fungus disease has been noticed attacking twigs and small branches near the tops of the trees. It causes the leaves to turn yellow and dry up, and kills the branch back for some distance. If examined while the injury is fresh, the surface of the bark looks, as has been aptly said, as if it had been dusted over with carbolic tooth powder. Later the coating turns from pink to grey, and scales off. The disease is also seen sometimes on cacao and pigeon pea, and has been found on oleander twigs in a garden.

The affected branches are often not noticed until they are quite dead, when their occurrence is vaguely attributed to 'borer'—an idea which is confirmed by the finding in them at that stage of beetle grubs such as commonly attack dead wood.

The disease has no connexion with the drying up of twigs and branches so commonly seen in dry or exposed districts, which may be due to starvation, wind, scale insects, or a variety of other causes. The pink colouration and its occurrence on otherwise healthy trees serve to distinguish it from the effects of any of these.

As seen so far, pink disease has been very scattered in its distribution, and cannot be said

to have caused any appreciable loss. A fungus which is closely similar if not actually the same as this is increasing on plantation rubber trees in Malaya, and there is always a chance that conditions may one day favour a more serious outbreak on lime trees in Dominica or St. Lucia. For this reason it is desirable that planters should learn to recognize the disease.

Treatment. The simplest and most effective way to treat the disease is by cutting off the branch on which it occurs at its junction with the next older branch or the stem, taking care to cut well below the affected part. The branch removed should be burnt or buried.

APPENDIX.

Lime-sulphur Solution.

Unslaked lime	50 lb.
(or freshly slaked lime	70 lb.)
Flowers (or flour) of sulphur	100 lb.
Water	50 gals.

Mix well with half the water, then add the other half. Boil for one hour in an iron boiler, which must be of sufficient size to contain the large amount of froth formed in the early stages. Stir continually at first ; do not let the fire get fierce ; avoid the splashes. Add water from time to time to replace that lost in boiling. The result is stock solution, which may be stored if kept in full drums or barrels, or covered with a layer of crude oil or kerosene, so that a minimum of air has access to it.

If the available boiler is small, half the quantity of water may be kept back until boiling is complete. The resulting solution is not quite so good.

For use as bark wash 1 gallon of the stock solution is added to 7 gallons of water. It may be used stronger, say 1 to 5, if found necessary.

It may be applied by means of a spraying machine, or a brush or a swab tied to a stick. It has a strong caustic action, and whatever is used should be well washed in water immediately afterwards. Contact with the skin or clothes should be avoided. Copper vessels should on no acconnt be used.

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